Evaluating Noncancer Health Risks from Inhaled PCBs

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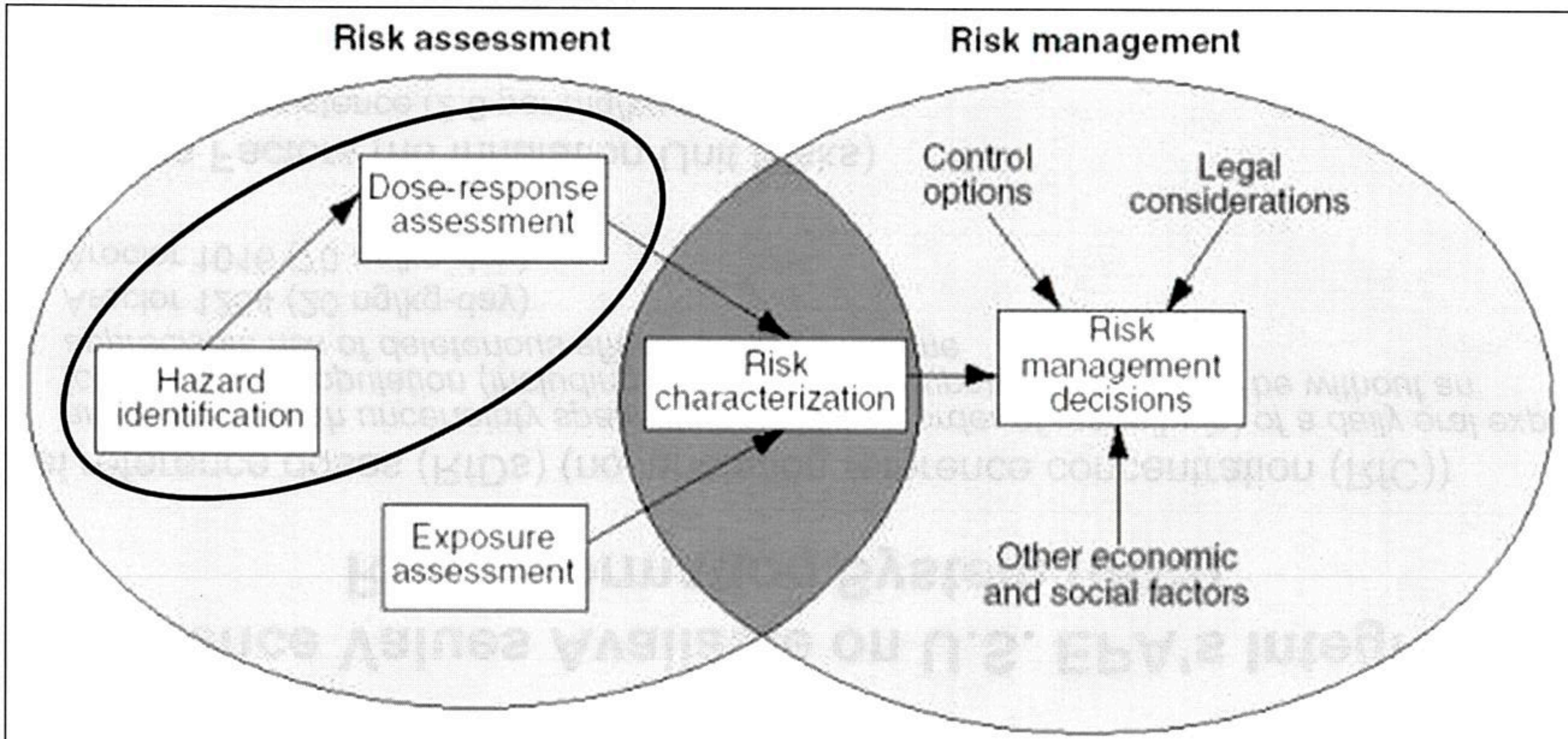
Overview

- Human health risk assessment of inhaled PCBs
  - Hazard identification
  - Dose-response assessment
  - Exposure assessment
  - Current approaches to minimize risk
- Uncertainties and research needs

The views expressed here are those of the author and do not necessarily reflect the views or policies of the U.S. EPA.

Human health risk assessment of inhaled PCBs



Source: EPA Office of Research and Development.

Reference Values Available on U.S. EPA's Integrated Risk Information System (IRIS)

- Oral reference doses (RfDs) (no inhalation reference concentration (RfC))
  - *an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime*
  - Aroclor 1254 (20 ng/kg-day)
  - Aroclor 1016 (70 ng/kg-day)

- Oral Slope Factors (no Inhalation Unit Risks)
  - High risk/persistence (2.0 per mg/kg-day)
  - Low risk/persistence (0.4 per mg/kg-day)
  - Lowest risk/persistence (0.07 per mg/kg-day)

- Route-to-route extrapolation (e.g. oral-to-inhalation)
  - PCB toxicity is not expected to vary based on route of exposure.
  - Metabolic pathways are similar by each route.
  - Critical effects are systemic, and PCBs are generally not associated with respiratory effects.
  - PCBs are well-absorbed through both oral and inhalation routes.

Toxicological Database Supporting Public Health Levels

Outcome	Human (in vivo) Studies	Animal (in vivo) Studies	Lowest Adverse Effect Level (LOAEL) (mg/kg-day)
Reproductive	+	+++	0.08 (monkey)
Developmental	+	++	0.028 (monkey)
Neurological	++	+	0.006 (monkey)
Hepatic	+	++	0.06 (rats)
Gastrointestinal	+	+	0.94 (pigs)
Endocrine	-	++	0.09 (rats)
Metabolic Disease	+	-	N/A
Respiratory	+	+	0.94 (pigs)
Cardiovascular	-	-	N/A
Immunologic	+	+++	0.005 (monkey)
Dermal	+	++	0.005 (monkey)
Ocular	+	+	0.005 (monkey)

Aroclor 1254 RfD Derivation

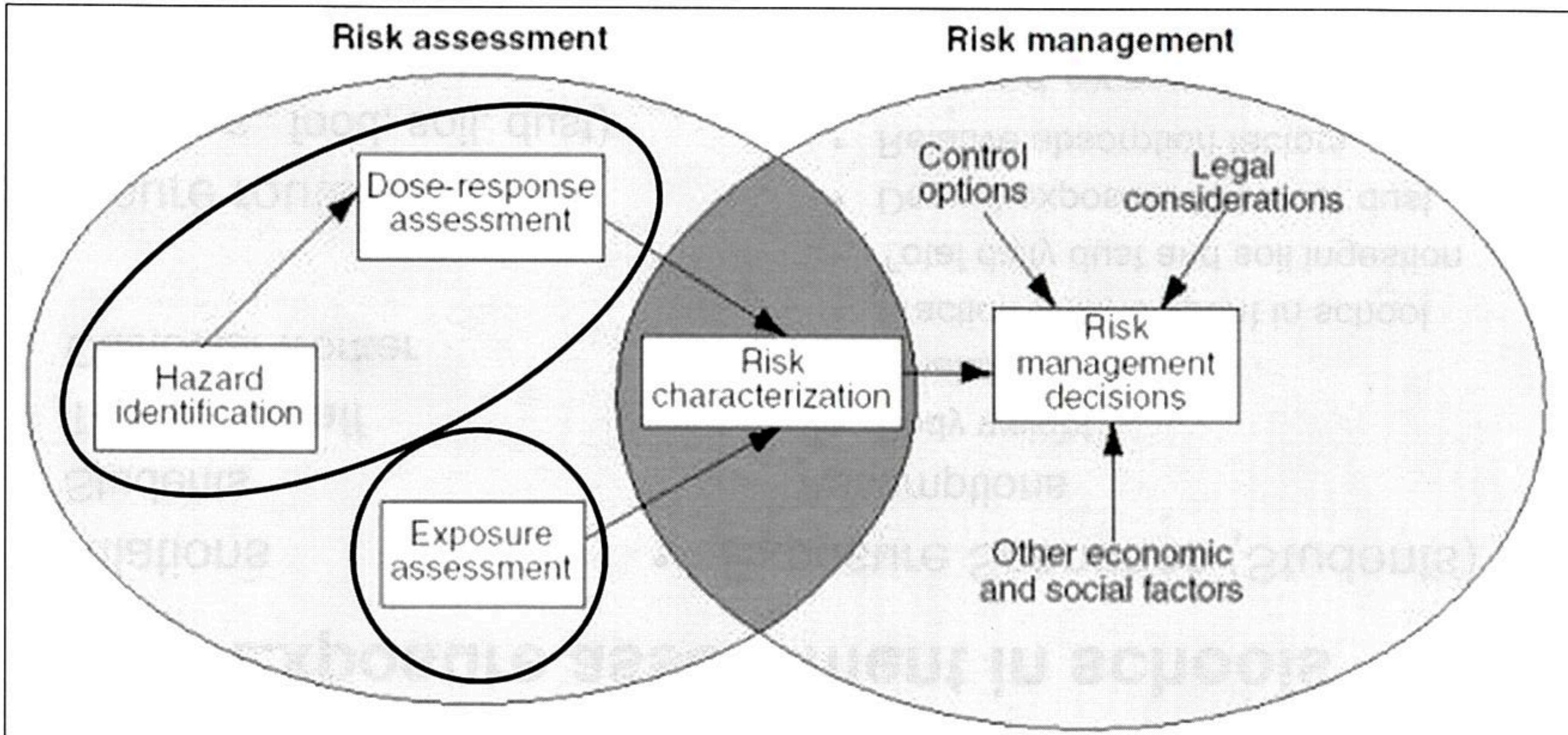
<u>LOAEL (immunotoxicity)</u>
0.005 mg/kg-day
= 5,000 ng/kg-day

<u>Uncertainty Factors</u>
$\div 10$
(sensitive populations)
$\div \sqrt{10}$
(monkeys ≠ humans)
$\div \sqrt{10}$
(effect at lowest tested dose)
$\div \sqrt{10}$
(study duration)

<u>Aroclor 1254 RfD</u>
20 ng/kg-day

An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime

Do PCBs in indoor air pose a health risk?



Source: EPA Office of Research and Development.

Exposure assessment in schools

- Populations
  - Students
  - Teachers/staff
  - Custodial worker
- Exposure routes
  - Oral (e.g., food, soil, dust)
  - Inhalation (e.g., indoor air)
  - Dermal (e.g., contact with soil and dust)

- Exposure Scenarios (Students)
  - Assumptions
    - Body weight
    - Inhalation rate
    - Fraction of time spent in school
    - Total daily dust and soil ingestion
    - Dermal exposure to indoor dust
    - Relative absorption factors
  - Background exposures
    - Dust and soil ingestion
    - Indoor (non-school) and outdoor air inhalation
    - Dermal exposure to indoor dust
    - Dietary background (U.S. FDA Market Basket Study)

U.S. EPA. (2011) Exposure factors handbook 2011 edition (final). EPA/600/R-09/052F. Washington, DC:U.S. Environmental Protection Agency. Available: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=236252.

Risk Characterization

Derived public health levels (PHLs) for PCBs in indoor air that would ensure an overall PCB exposure ≤ 20 ng PCB/kg-day (IRIS RfD for Aroclor 1254), taking into account background exposures.

$$\text{PHL (ng/m}^3\text{)} = \frac{(\text{RfD (ng/kg/day)} - \text{Background Dose (ng/kg/day)}) \times \text{BW (kg)}}{\text{Inhalation Rate (m}^3\text{/day)} \times \text{Relative Absorption} \times \text{Fraction of time spent in school}}$$

Public Health Levels of PCBs in School Indoor Air (ng/m³)						
Age 1-<2 yr (Daycare)	Age 2-<3 yr (Daycare)	Age 3-<6 yr (Preschool)	Age 6-<12 yr (Elementary School)	Age 12-<15 yr (Middle School)	Age 15-19 yr (High School)	Age 19+ yr (Adults)
70	70	100	300	450	600	450

Why Different PHLs for Different Age Groups?

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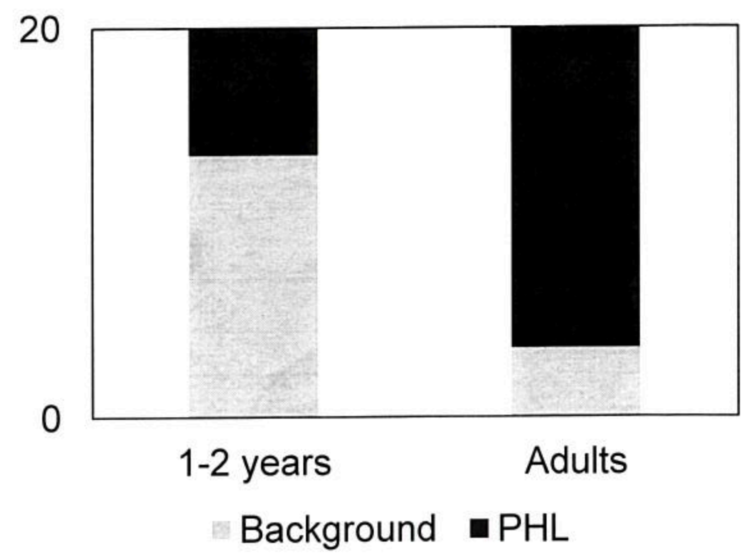
Exposure Factor (EF)	EF Data Used	
	Children 1-2 years	Adults
Dust Ingestion Rate	60 mg/d	27.5 mg/d
Soil Ingestion	50 mg/d	22.5 mg/d
Inhalation Rate	8.0 m^3/d	15.9 m^3/d
Skin Surface Area	1,155 cm^2	5,000 cm^2
Dust Adherence Factor	0.006 mg/cm^2-d	0.003 mg/cm^2-d
Body Weight	11.4 kg	71.8 kg
Time Spent Indoors	23.4 h/d	19.3 h/d



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Exposure Factor (EF)	EF Data Used		EF Data Normalized to Body Weight	
	Children 1-2 years	Adults	Children 1-2 years	Adults
Dust Ingestion Rate	60 mg/d	27.5 mg/d	5.3 mg/kg-d	0.4 mg/kg-d
Soil Ingestion	50 mg/d	22.5 mg/d	4.4 mg/kg-d	0.3 mg/kg=d
Inhalation Rate	8.0 m^3/d	15.9 m^3/d	0.7 m^3/kg-d	0.2 m^3/kg-d
Skin Surface Area	1,155 cm^2	5,000 cm^2	101 cm^2/kg	70 cm^2/kg
Dust Adherence Factor	0.006 mg/cm^2-d	0.003 mg/cm^2-d	5.3E-4 mg/cm^2-kg-d	4.3E-5 mg/cm^2-kg-d
Body Weight	11.4 kg	71.8 kg	--	--
PCB Dietary Intake	0.008 µg/kg-d	0.002 µg/kg-d	0.008 µg/kg-d	0.002 µg/kg-d

Assumptions and Uncertainties

- PHLs are calculated using background exposure data that may or may not accurately characterize background exposures at a particular site of interest.
- PHLs are calculated using the RfD for Aroclor 1254, which assumes that an estimate of a safe level of oral exposure can be used to estimate a safe level of inhalation exposure

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70	**70**	**100**	**300**	**450**	**600**	**450**

PCB Exposure Sources Included in PHL Calculations

- Indoor air (background) = 6.9 ng/m^3
  - Based on mean total PCB concentration in air from 10 homes in Toronto, Canada*
- Dust (school and non-school) = 0.22 µg/g
  - Based on mean total PCB concentration in dust samples collected from 20 homes in Austin, TX*
- Soil (school and non-school) = 0.05 µg/g
  - Based on samples collected from parks in Helsinki, Finland[+]
- Outdoor air (school and non-school) = 0.5 ng/m^3
  - Based on average total PCB concentration in outdoor air in Toronto, Canada*
- Food (based on FDA total diet study[‡]) = 2-8 ng/kg-day (varies by age)

* Harrad et al. (2009) Polychlorinated biphenyls in domestic dust from Canada, New Zealand, United Kingdom and United States: Implications for human exposure. *Chemosphere* 76: 232-238.

[+] Priha et al. (2005) PCB contamination from polysulfide sealants in residential areas - exposure and risk assessment. *Chemosphere* 59: 537-543.

‡ Agency for Toxic Substances and Disease Registry (2000) *Toxicological Profile for PCBs*. Available at: http://www.atsdr.cdc.gov/toxprofiles/index.asp.

Impact of Site-Specific Exposure Data (Example Calculation)

PHL for elementary school children (6-12 years of age) = 300 ng/m^3

- Indoor air (background) = 6.9 ng/m^3
- Outdoor air (school and non-school) = 0.5 ng/m^3
- Dust (school and non-school) = 0.22 µg/g
- Soil (school and non-school) = 0.05 µg/g
- Food (based on FDA total diet study) = 3 ng/kg-day
- If PCBs in school indoor air are 300 ng/m^3, **total exposure = RfD (20 ng/kg-d)**

Impact of Site-Specific Exposure Data (Example Calculation)

What if PCBs in dust and soil at the school are also elevated?

- Indoor air (background) = 6.9 ng/m^3
- Outdoor air (school and non-school) = 0.5 ng/m^3
- Dust (non-school) = 0.22 µg/g (school) = 2.2 µg/g
- Soil (non-school) = 0.05 µg/g (school) = 0.5 µg/g
- Food (based on FDA total diet study) = 3 ng/kg-day
- If PCBs in school indoor air are 300 ng/m^3, **total exposure (elementary school children 6-12 years of age) > RfD (21 ng/kg-d)**

Impact of Site-Specific Exposure Data (Example Calculation)

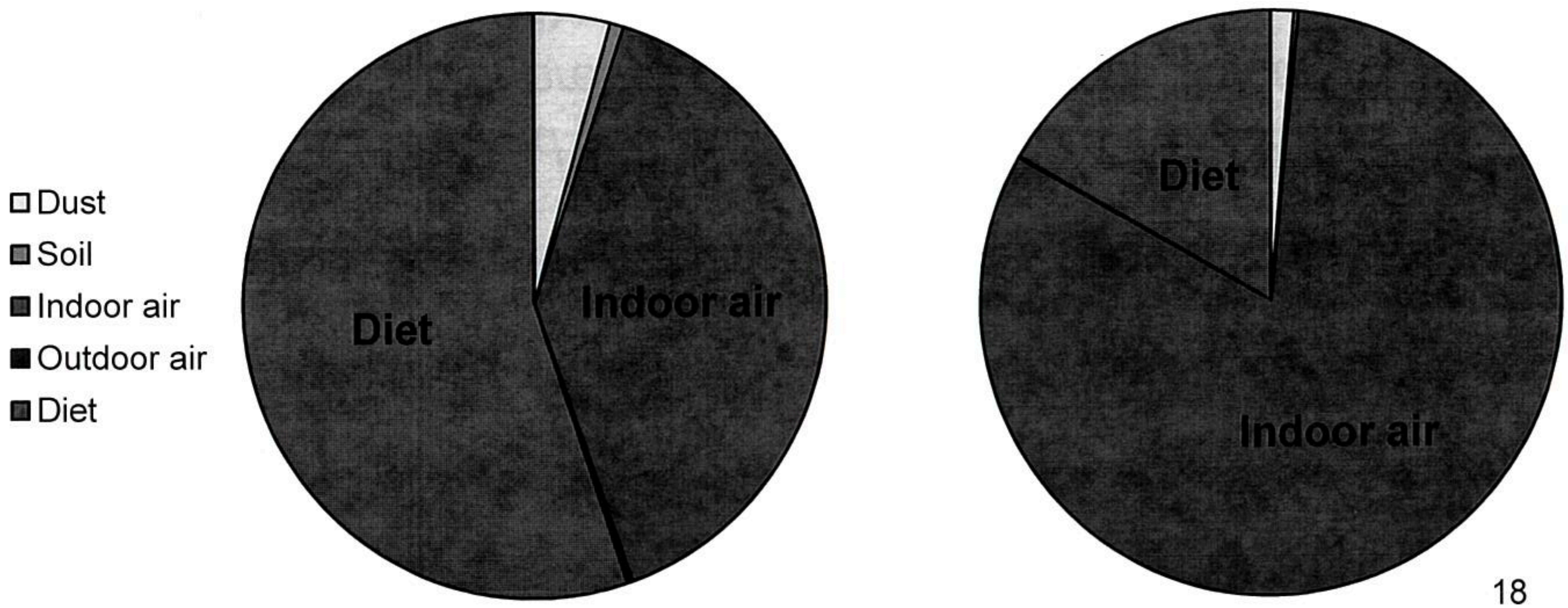
What if PCBs in dust and soil at the school are elevated, but background exposures are less than those used to calculate the PHL?

- Indoor air (background) = 2.8 ng/m^3
- Outdoor air (non-school) = 0.1 ng/m^3 (school) = 0.5 ng/m^3
- Dust (non-school) = 0.11 µg/g (school) = 2.2 µg/g
- Soil (non-school) = 0.005 µg/g (school) = 0.5 µg/g
- Food (based on FDA total diet study) = 3 ng/kg-day
- If PCBs in school indoor air are 300 ng/m^3, **total exposure (elementary school children 6-12 years of age) < RfD (19 ng/kg-d)**

Relative Contributions of Various Sources of PCB Exposure

School indoor air PCB levels at background
Children (6-12 years of age)

School indoor air PCB levels at 300 ng/m³
Children (6-12 years of age)



Impact of Site-Specific Exposure Data (Example Calculation)

What if PCBs in dust and soil at the school are <u>not</u> elevated and most background exposures are <u>less</u> than those used to calculate the PHL, but dietary exposure is elevated (e.g., high sport-fish consumption)?

- Indoor air (background) = 2.8 ng/m^3
- Outdoor air (non-school) = 0.1 ng/m^3 (school) = 0.5 ng/m^3
- Dust (non-school) = 0.11 µg/g (school) = 0.22 µg/g
- Soil (non-school) = 0.005 µg/g (school) = 0.05 µg/g
- Food = 6 ng/kg-day
- If PCBs in school indoor air are 300 ng/m^3, **total exposure (elementary school children 6-12 years of age) > RfD (22 ng/kg-d)**

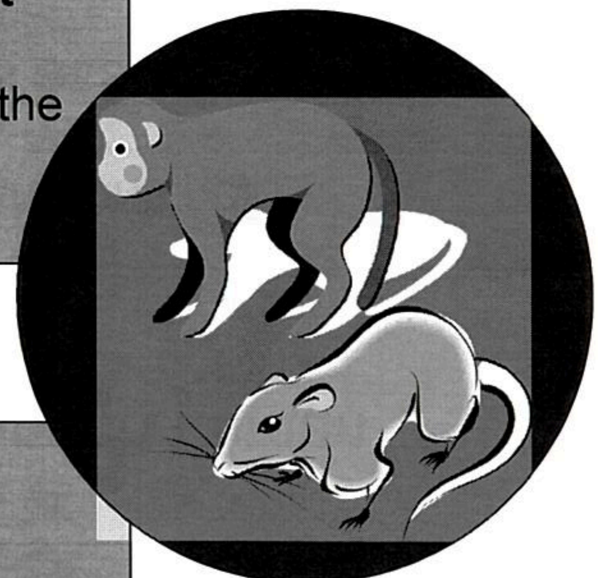
Assumptions and Uncertainties

- PHLs are calculated using background exposure data that may or may not accurately characterize background exposures at a particular site of interest.
- PHLs are calculated using the RfD for Aroclor 1254, which assumes that an estimate of a safe level of oral exposure can be used to estimate a safe level of inhalation exposure
  - PCB toxicity is not expected to vary based on route of exposure.
  - Metabolic pathways are similar by each route.
  - Critical effects are systemic, and PCBs are generally not associated with respiratory effects.
  - PCBs are well-absorbed through both oral and inhalation routes.

What Research Would Reduce Uncertainty?

Accurate Exposure Assessment

- What is the congener profile of the PCB mixture?



Comprehensive Health Effect Evaluation

- Developmental neurotoxicity
- Immunotoxicity
- Changes in thyroid hormone levels

Lehmann et al. (2014) Evaluating Health Risks from Inhaled Polychlorinated Biphenyls: Research Needs for Addressing Uncertainty. *Environ Health Perspect* In Press.

Summary

- EPA guidance and tools are available to support human health risk assessment of inhaled PCBs
  - http://www.epa.gov/osw/hazard/tsd/pcbs/
  - http://www.epa.gov/pcbsincaulk/pdf/maxconcentrations.pdf
- New research is needed on the health effects associated with PCB inhalation in humans and animals

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